ROBOT SENSING AND NAVIGATION – LAB3

IMU SENSOR DATA COLLECTION AND ANALYSIS

COURSE CODE: EECE5554
PROFESSOR: Dr. Hanumant Singh
NAME: Gautham Ramkumar
NUID: 002308559

AIM:

To create packages for an IMU sensor using ROS2 Humble, write a driver code for the sensor to collect data and analyze them.

DATA COLLECTION:

The driver code for the VN-100 IMU sensor was written using python to read strings that starts with $VNMYR. The $VNMYR is one of the output formats of the VN-100 IMU sensors that represents orientation data in terms of Roll, Yaw and Pitch in 3D space. Two sets of data were collected.

- Stationary data where the IMU sensor is kept sensor in an environment away from vibrations and electronic devices for 10-15 minutes.
- A five hour long data where again the IMU sensor is kept away from electronic devices.

Both the stationary data and the five hour data was collected at 7 North Avenue, Roxbury.

STATIONARY DATA ANALYSIS:

In Fig 1, we can clearly see that all three orientation angles – roll, yaw and pitch didn't change much during the 15 minute time frame. Roll changes between 0.66 to 0.69, Yaw's initially at -7.4 and then gradually decreases to -7.8. After reaching -7.8 it starts increasing. Pitch is initially at 1.60 and gradually increases to 1.65. In an ideal world, the orientation plots would be a straight line but since we collected data in a real world we can see how the external factors like vibrations, electronic devices, temperature affect and noise affect the data.

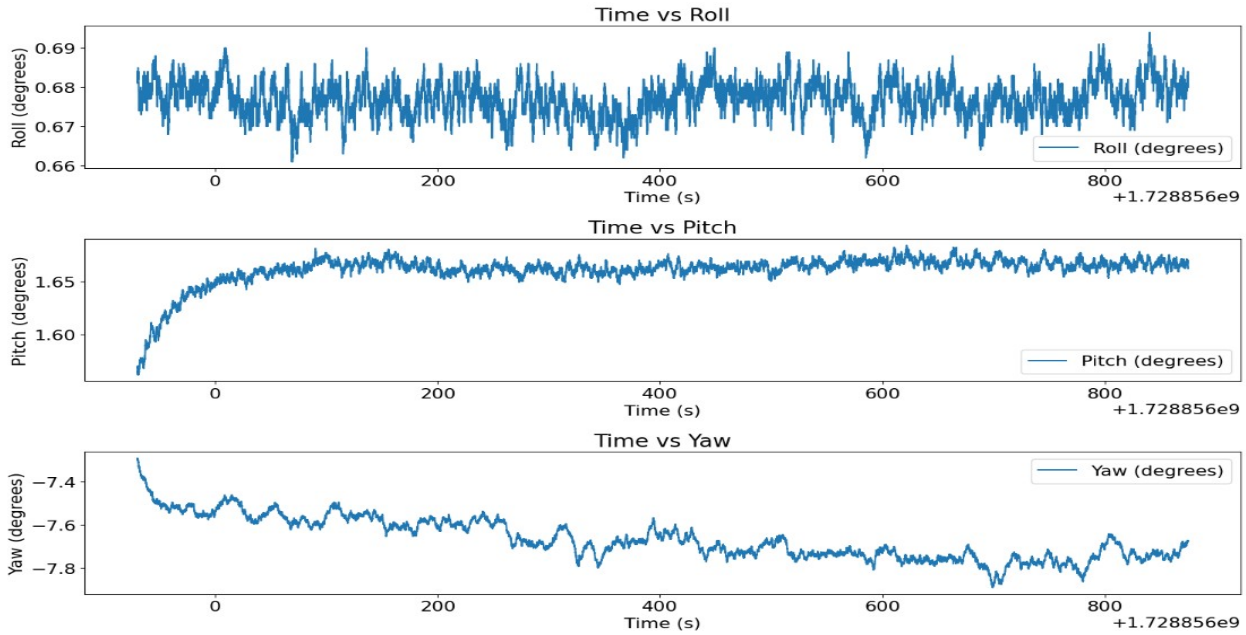

Fig 1 Time vs Orientation Plots

In Fig 2 and 3 we can see how the angular velocity and linear acceleration stays the same throughout the interval with some minor fluctuations. Angular velocity of x and z graphs are similar, which indicates there might be more disturbances in the y-axis. Similarly, for linear acceleration, the graphs of x and y axes are similar indicating slight noise in z-axis.

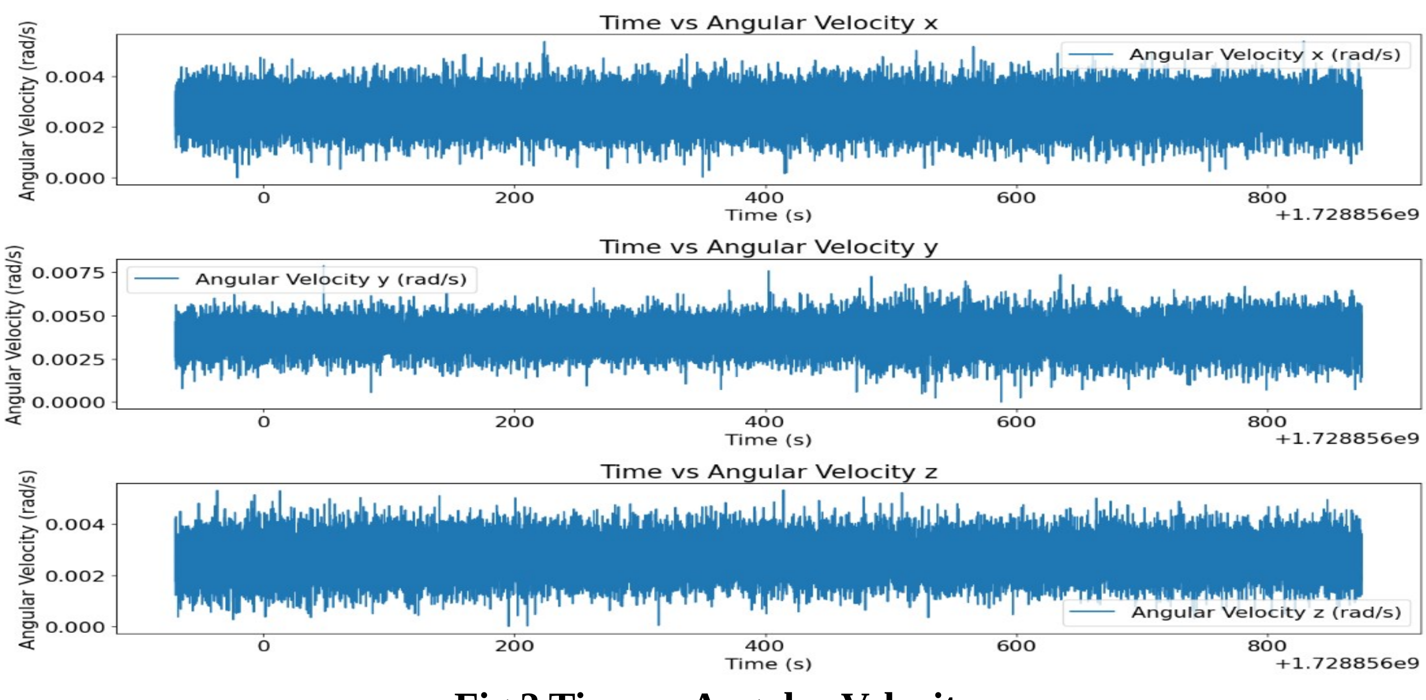

Fig 2 Time vs Angular Velocity

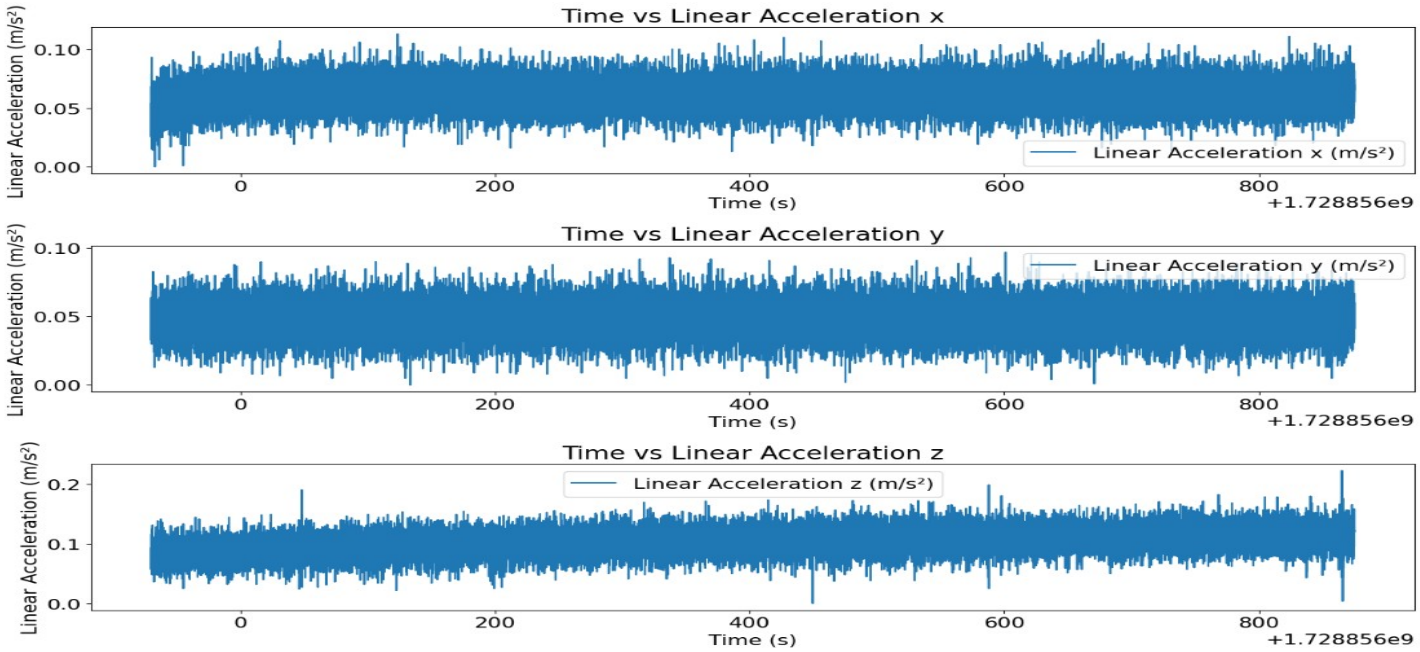

Fig 3 Time vs Linear Acceleration

In Fig 4 we can see how the IMU sensor is actually affected by noise, mainly due to electromagnetic interferences. All three axes have been greatly affected by environmental magnetic interference. In the x-axis, we can see a sudden spike which is definitely due a magnetic interference. In the y-axis, there is no sudden spike but the magnetic field value ranges from 0 to 200 gauss and in z-axis the value range increases from 100-200 to 0-200 in the near end.

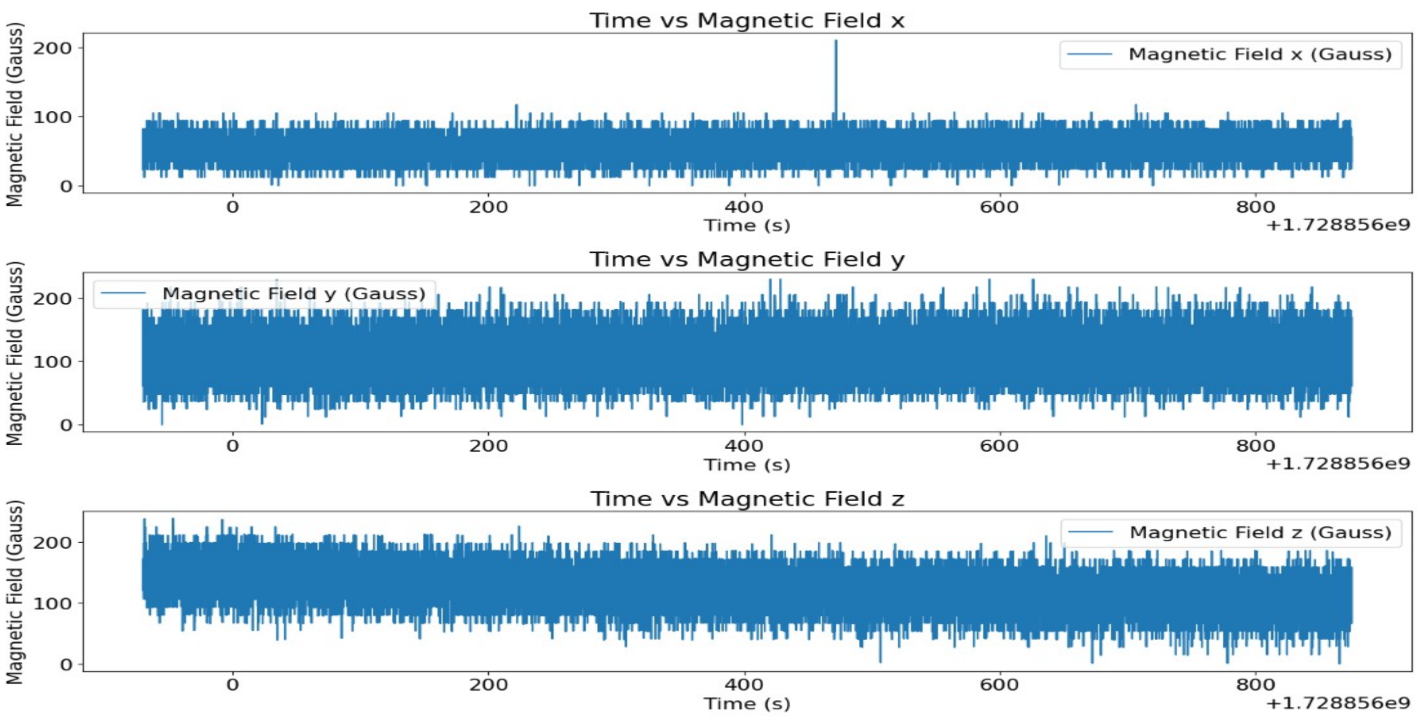

Fig 4 Time vs Magnetic Field Plots

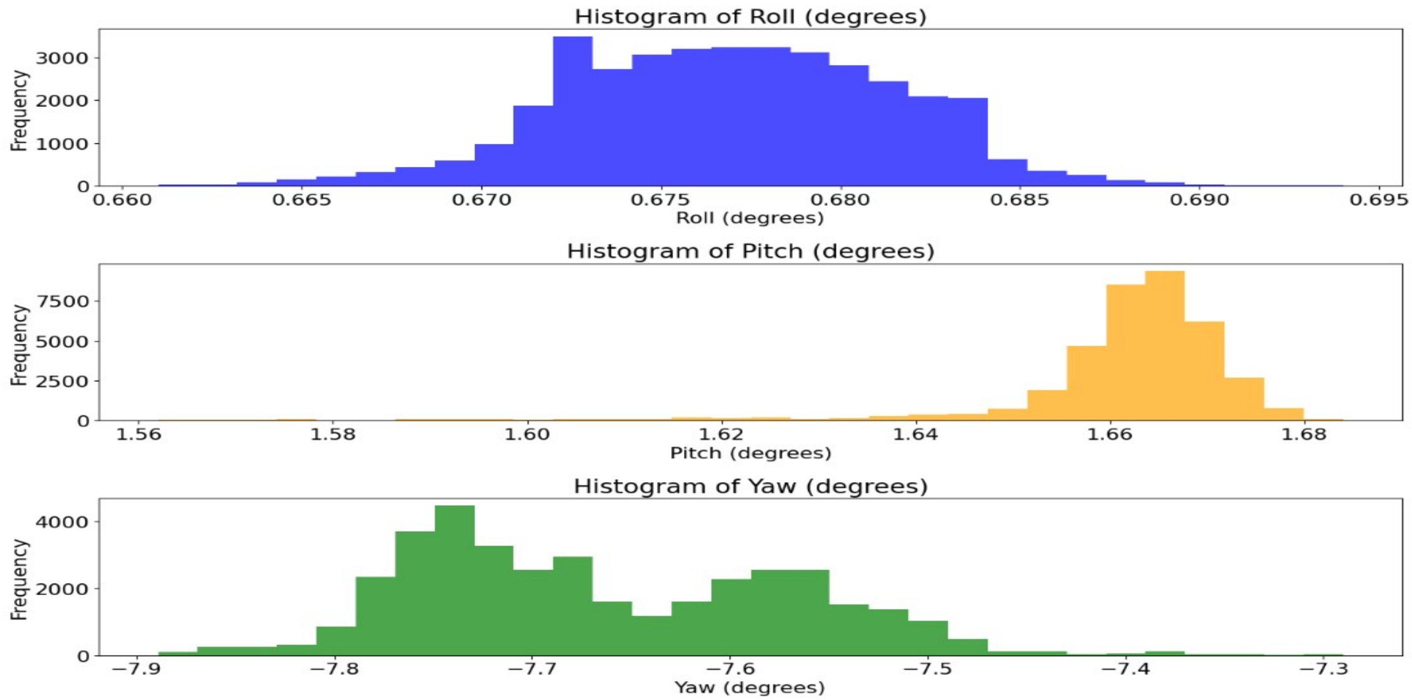

Fig 5 Histogram Plots of Orientation Angles

From fig 5 we can say that the standard deviation of Roll is relatively high compared to Pitch and Yaw since its spread out. Since the standard deviation is high for Roll, we can say that it's noise level is also high compared to Pitch and Yaw and out of all orientation angles we can say that Pitch is relatively stable.

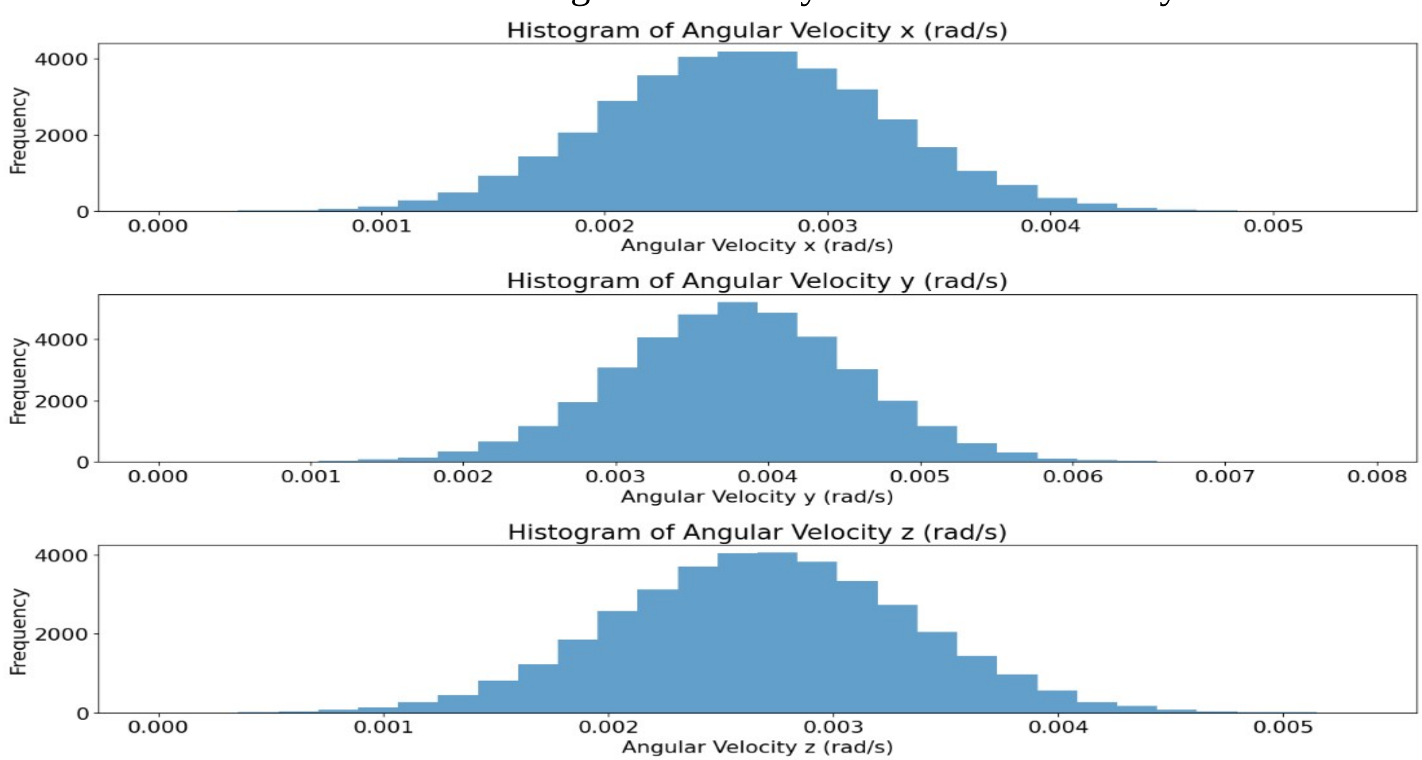

Fig 6 Histogram Plots of Angular Velocity

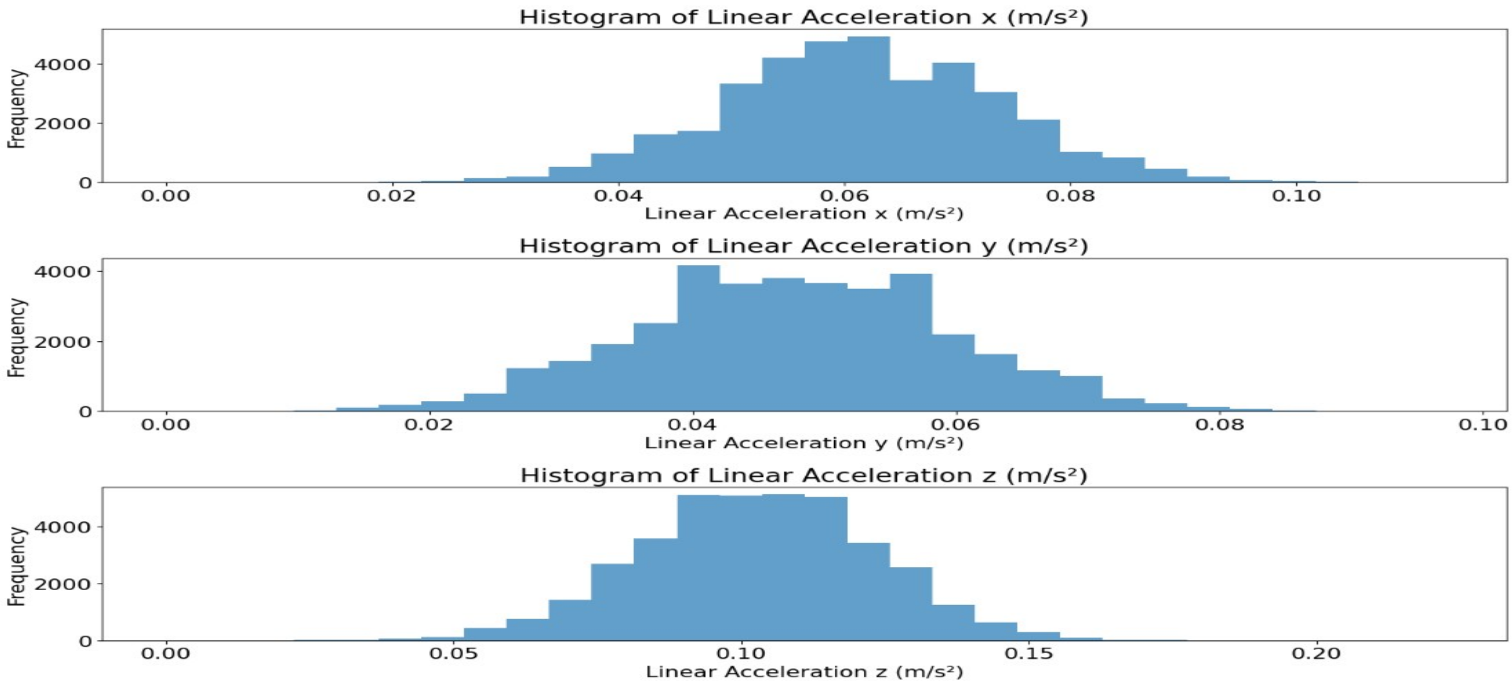

Fig 7 Histogram Plots of Linear Acceleration

From fig 6 and 7 we can see that the histograms of angular velocity and linear acceleration are similar to normal distribution, indicating that the mean can be found near the peak of the histograms. The spread of the graphs when comparing with the mean is not much since all the graphs are centered around small values. So we can infer that noise is small since the standard deviation is also small.

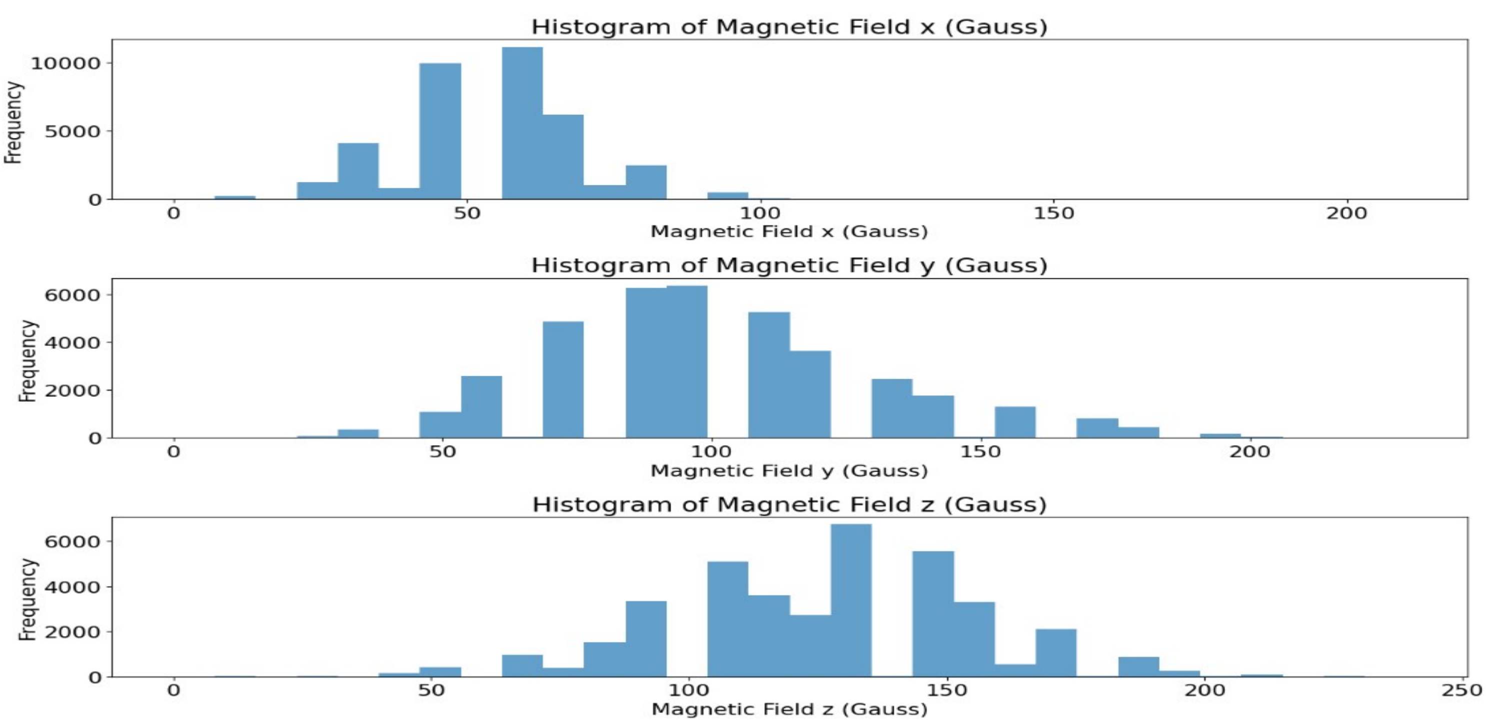

Fig 8 Histogram Plots of Magnetic Fields

From 8 we can see that x-axis is the least spread compared to y and z axes, indicating that the magnetic field in x-axis is stable compared to other axes. The spread is similar for y and z axis. So, the noise is more in both y and z axes.

FIVE HOUR DATA ANALYSIS:

RosBag Link: Google Drive Link

Fig 9, 10 and 11 represents the Allan deviation curves for accelerometer, magnetometer and gyroscope respectively across all its three axes. Allan Deviation Curve is a test for stability for sensors by quantifying the noise characteristics of the tool.

Quantization Noise: Quantization noise arises due to the finite resolution of digital sensors, where the sensor's continuous analog signal is discretized into steps during digitization. The sensor can only measure in fixed increments, leading to small errors.

Bias Instability: Bias instability refers to slow-changing, long-term drifts in the sensor's output due to random, low-frequency noise processes. It represents how the bias (constant error) of the sensor varies over time, primarily caused by thermal variations or material instabilities within the sensor.

Random Walk: Random walk is a type of noise that accumulates over time. For gyroscopes, this is often referred to as Angle Random Walk (ARW), and for accelerometers, it is Velocity Random Walk (VRW). It occurs when random fluctuations cause the measured value (e.g., angular velocity or linear acceleration) to drift in a random manner, accumulating with time.

From fig 9 we can see that random walk and bias instability is constant for all three axis but quantization noise is varying. The source of noise for accelerometer is quantization noise but from the graph it is very clear that the accelerometer is stable and can be used for precise calculations.

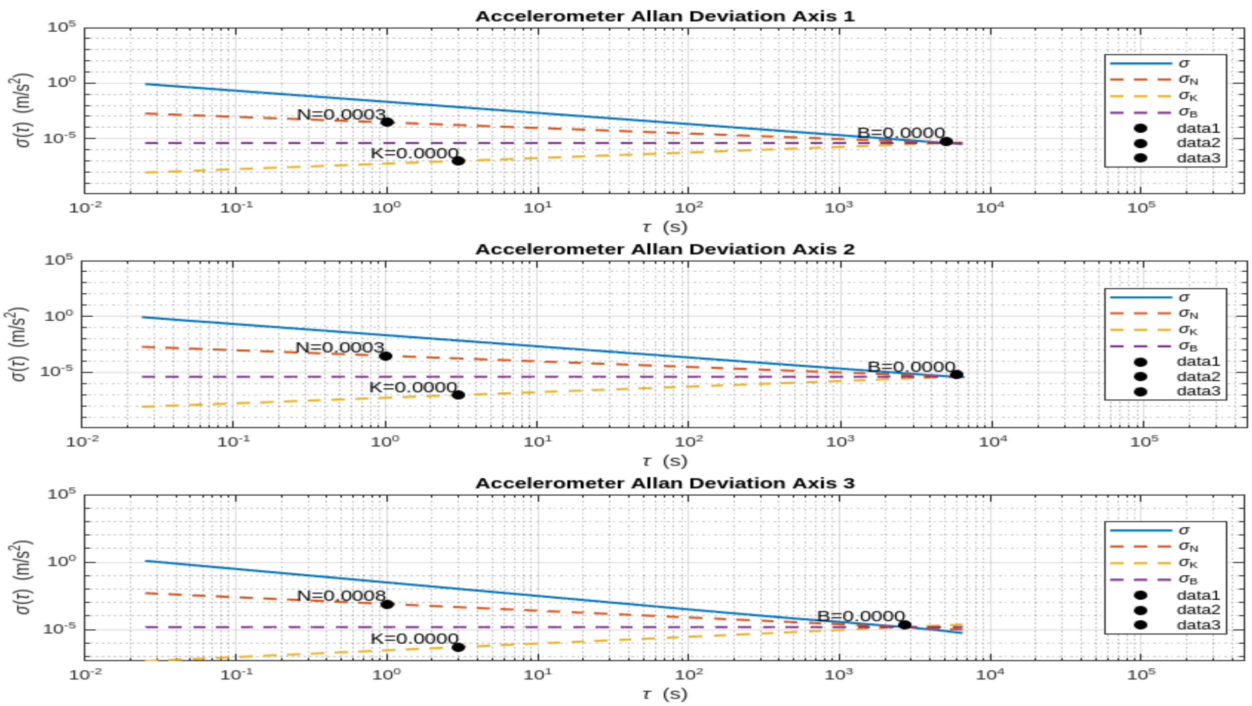

Fig 9 Allan Deviation Curve for Accelerometer

From fig 10 it can be seen that all the parameters are changing for all three axis. It can be clearly seen from the graph that all the parameters are big in number compared to other sensors. The source of error for magnetometer is Random Walk, as you can see, Random Walk is high in all the axes.

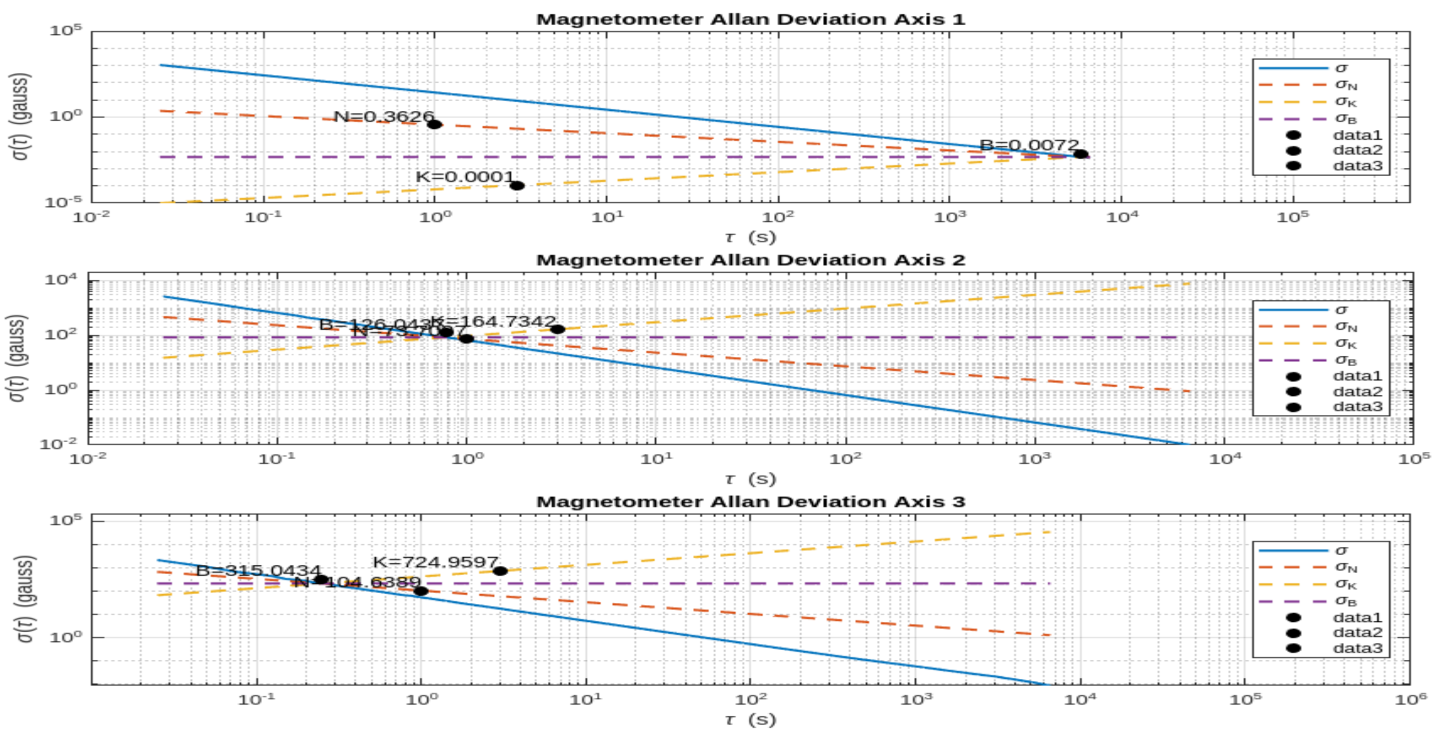

Fig 10 Allan Variance Curves for Magnetometer

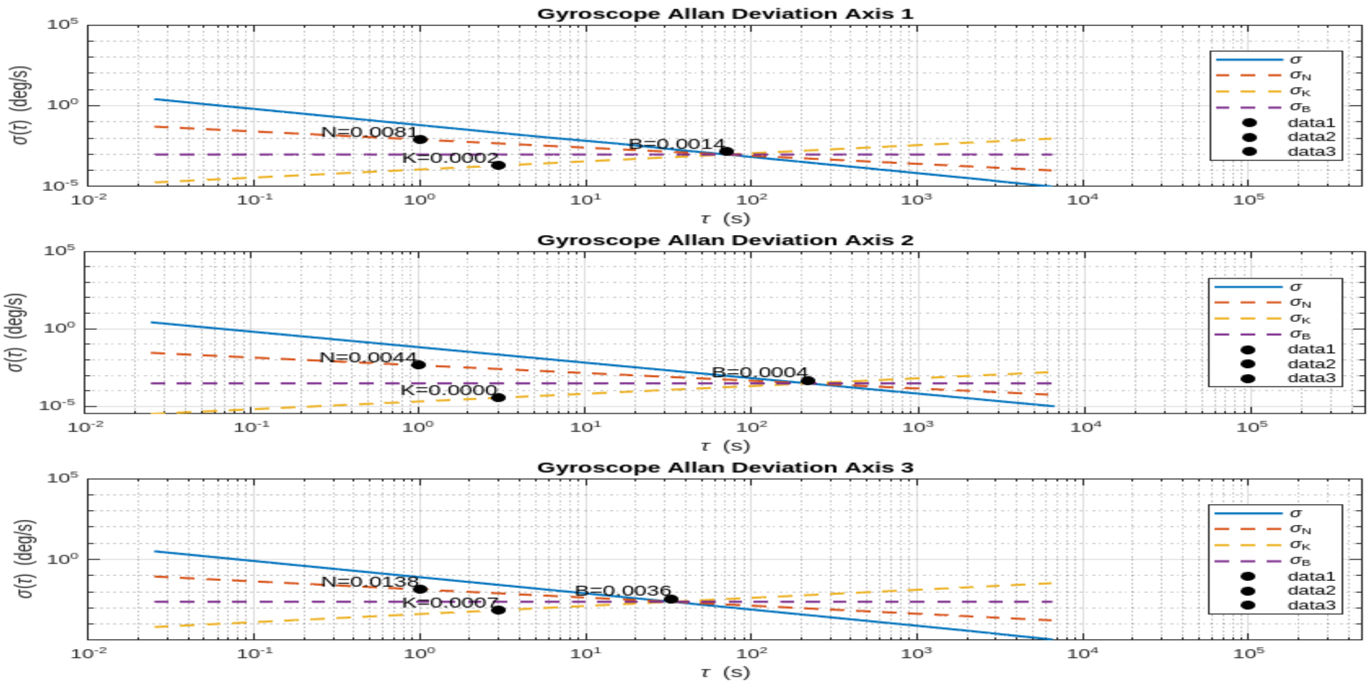

Fig 11 Allan Variance Curves for Gyroscope

Fig 11 depicts the Allan Deviation curve of a Gyroscope and it can be seen that in all the three axes Random Walk is really negligible (0.0002, 0.0000, 0.0007). The Quantization Noise is the source of error for Gyroscope. The Bias Instability remains low for all the three axes (0.0014, 0.0004, 0.0036).

<u>VN-100 DATA SHEET COMPARISION:</u>

ACCELEROMETER:

According to the data sheet provided, the bias stability should be less than 0.04mg and B=0 in all the three axes which is within the range.

According to the data sheet provided, the noise density i.e quantization noise should be less than 0.14 and noise density is very negligible in all three axes which is within the range.

MAGNETOMETER:

According to the data sheet provided, the noise density i.e quantization noise should be less than 140 and noise density is very negligible in the first axis, and close to 140 in the second axis and around 73 in the third axis which is well within the range.

GYROSCOPE:

According to the data sheet provided, the bias stability should be less than 10 and the bias stability is very small when compared to 10. Thus, the values are well

within the range.
According to the data sheet provided, the noise density i.e quantization noise should be less than 0.0035 and noise density is slightly above in Axis 1 and 2 of the gyroscope.

<u>MEASUREMENT AND MODELING:</u>

- **Quantization Noise:** Observed at short intervals especially when the Allan Deviation curve is flat. Modeled as a discrete function since its finite.
- **Bias Instability:** Represented by the minimum point on the Allan Deviation curve. Considered as a constant offset that varies with time slowly.
- **Random Walk:** Identified by a slope of -0.5 in the Allan Deviation Curve. Modeled like brownian motion.